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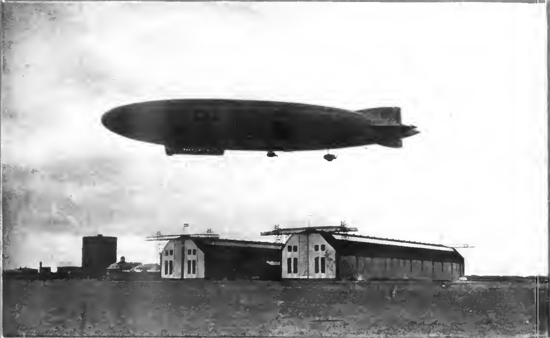

German Air Transport: The Zeppelin Liner Bodensee

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VOLUME VII
Number 5

Three Dollars a Year

SPECIAL FEATURES

AIRPLANE ENGINE VIBRATION
SOME INTERESTING GERMAN AIRPLANES
PROPELLER AND FUSELAGE AIR PRESSURE INTER-ACTION
BRITISH AIRPLANE AND SEAPLANE COMPETITION
DOPING AIRPLANE LINEN

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AVIATION AND AERONAUTICAL ENGINEERING

VOL. VII. NO. 5

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AVIATION AND AERONAUTICAL ENGINEERING

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Vol. VII October 1, 1919 No. 5

IN the present issue there are presented to the reader a number of documents, verbal and pictorial, which furnish food for considerable thought to those concerned with the development of American aeronautics.

Perhaps the most striking of these is the illustration on the cover, which shows the first merchant Zeppelin built since the signing of the armistice. With accommodations for thirty-five passengers and a maximum speed of 75 m. p. h., this ship is used on a daily service between Berlin and Friedrichshafen. Thus Germany, beaten in the field and forced to sign a humiliating and onerous peace, gives the victorious Allies an object lesson with regard to the commercial utilization of airships.

Elsewhere in this issue are shown a set of pictures illustrating some of Germany's last efforts in the field of military aviation and which are of interest mainly because they prove that our late enemies did not standardize their military airplanes to such extent as it was generally assumed. Now that the peace treaty forbids Germany from maintaining an air force, all German aeronautical efforts are concentrated in the development of air transport; and the magnitude of the effort furnished may be gathered from the fact that at the present time thirteen airplane lines for the carriage of passengers, goods and mail are in operation, while six additional lines are projected. Some of these services have been run since February last—which makes one think that Germany, expecting to be stripped of her air force, turned her attention to the development of air transport as soon as the Armistice was signed.

The provisions of the British aircraft competition, which are also printed in this issue, afford on the other hand an instance how Great Britain intends to develop a standard of safety and reliability in commercial aviation. Some of these requirements seem extremely difficult to fulfill, but the science of aeronautics is making such extraordinary strides that by next spring these difficulties undoubtedly will have been overcome.

How the United States proposes to encourage and assist the development of commercial aircraft is unfortunately still an unknown quantity.

The Aviette

News is reaching us both from France and Germany, of reawakened interest in so-called "aviettes" or airplanes driven by man-power.

In France Poulain has succeeded in making a flight of 12 metres upon a flying bicycle. In Germany a machine of 45 feet span and a length of 25 feet, propelled by the working up and down of the wings by the pilot is said to have reached a height of 15 feet, but without being able to make headway.

When we consider how rapidly the motorbicycle has displaced the ordinary man-driven bicycle, it is hardly to be expected that man-driven airplanes will be ever built in large quantities.

Moreover if we make a few rough calculations to find the power which a man would have to exert in order to operate the screw of a small machine, with presumably about the efficiency of an ordinary airplane, we find the requirements far beyond his powers. An athlete in a short sprint may exert 1½ h. p., but to sustain even ½ h. p. for an hour would be a physical impossibility. Consequently, as a new satisfactory, and reliable means of locomotion the "aviette" would hardly seem promising.

It offers, however, the possibility of a new and thrilling sport, and it has this one advantage over the ordinary road bicycle that just as a sailing vessel can utilize the strength of the wind, so a man driven plane may become a soaring machine, the passenger gradually learning to utilize upward currents, and tail-on winds. The soaring flight of birds has so far remained a mystery, but there is probably a very rational, mechanical explanation of such flight, and man learning to soar like some birds will soon be able to discover a rational solution for this mystery.

The construction of small machines in which sustentation and propulsion is effected by means of up-and-down motions of the wings, will also furnish the first rational test of the ornithopter principle. It is not too much to say that hundreds of such ornithopter machines have been invented, and much thought and energy expended without the slightest result. There at least we see a possibility of a practical study of the ornithopter, which will rapidly determine whether there is any value in the principle at all, or whether consideration of it should cease once and for all.

For these reasons, the aeronautical engineer will probably watch developments with skepticism, but interest nevertheless.

Civil Flying Developing

It is encouraging to note that despite the lack of official regulation of civil aerial transport, American airplane manufacturers report quite a large number of sales of airplanes to civilians. The Middle West, in particular, promises to become a flourishing field of activity, for a large demand begins to develop there for two and three seater land machines as well as for flying boats—symptoms which denote a healthy state of affairs.

Airplane Engine Vibration—II

By Glenn D. Angle

Engineer in Charge of Engine Design, Engineering Division, Air Service

Determining the degree of engine vibration resulting from torque reaction or torque variation is a complex problem. Since these vibrations appear coincident with those due to other sources it is practically impossible to distinguish them individually. Just what part of the total engine vibration is due to torque reaction or torque variation and the particular form in which it asserts itself depends entirely upon the

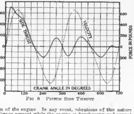


Fig 8 Piston Side Thrust

design of the engine. In any event, vibrations of this nature are always present while the engine is functioning and cannot be overcome, consequently our investigations can only deal with their effects.

The treatment of the subject as presented here is only for the purpose of acquainting the reader with some of the problems which must be considered in connection with the design of certain major engine components. In order to treat such a complex problem briefly, these investigations can only be of a general nature. The treatment is fairly complete, however, in respect to airplane engines inasmuch as torque curves are given covering the various types having practically all known numbers of cylinders in which the interval of firing is even, as well as a few in which the fire impulses are irregular.

No attempt will be made to investigate special cases of

Fig 9 Diagram of Torque Reaction

vibration relative to any particular engine type or to rate specific instances where vibrations as a result of torque reaction or torque variation have been observed. Such a subject could hardly be exhausted, and furthermore, since any conclusions drawn would be almost entirely based on theory, their practical value is to be questioned. The reader will have no difficulty, however, in successfully applying the data contained herein to his design problems.

Engine vibration as set up during the transmission of torque to the driving member will be investigated in two ways. Vibration due to torque reaction appears in the form of rocking couples at right angles to the crankshaft axis and its effects depend principally on the cylinder arrangement. The vibratory disturbances due to torque variations must be considered along the crankshaft axis, or as magnitude of turning moment for a complete cycle. Each will be taken up separately and in order.

Torque Reaction

One of the fundamental axioms of mechanics is that when a force is exerted there must be a reactionary force of equal magnitude in the opposite direction in order to prevent motion in space. In the case of a crank mechanism the reaction of crankshaft torque appears in the form of pressure between the cylinder and piston. Later it will be proven mathematically that the moment of this pressure about the crank center is equal to the torque of the crankshaft.

Since the cylinders and crankcase are prevented from rotating by the engine supports, it follows that it is at these points that the pressure between the cylinder and piston (commonly termed piston side thrust) is ultimately resisted. Obviously the crankcase must be of the proper tubular shape and strong enough in section to prevent distortions which in turn tend to produce fractures as a result of the vibrations set up

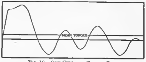


Fig 10 One-Cylinder Torque Curve

from variations in piston side thrust. The more cylinders there are in line the stiffer must be the crankcase and engine beds, also engines with individual cylinders require more careful attention in the design of the crankcase and engine beds than those in which the cylinders are tied rigidly together. Fig. 8 is given to illustrate the variation in side thrust during one complete cycle. The values were derived from a 4½ x 6 engine running at 2000 r.p.m.

It is interesting to note that the greatest side thrust occurs on the expansion stroke near the period of maximum piston velocity. This is due to the fact that when the piston velocity is greatest the connecting rod and crank throw are at right angles, and the rod is making its greatest angle with the cylinder axis. Any decrease in the length of the connecting rod accentuates this condition.

The piston side thrust has been partly diminished in some designs by offsetting the cylinders in respect to the crank axis. The wear on the piston and cylinder is decreased as a result of a more uniform side thrust. It is also to be expected that the more uniform torque reaction will somewhat tend to lessen vibration.

An arbitrary crank position with the simple trigonometric values of the various lines is shown on Fig. 9 for the purpose of deriving a formula for the side thrust moment about the crank axis. F the resultant force of gas pressure and inertia along the cylinder axis has been resolved into a force along the connecting rod axis and one at right angles to the cylinder wall. The latter force is equal to $F \tan \phi$. The moment arm of this force will be the sum of $\sqrt{l^2 - r^2 \sin^2\theta}$ and $r \cos\theta$. Letting F_r represent the moment the expression can be written

$$F_r = F \tan \phi \left(\sqrt{l^2 - r^2 \sin^2\theta} + r \cos\theta\right)$$

Substituting a value for $\tan \phi$

$$F_r = \frac{F_r \sin\theta}{\sqrt{l^2 - r^2 \sin^2\theta}}\left(\sqrt{l^2 - r^2 \sin^2\theta} + r \cos\theta\right)$$

Then

$$F_r = F_r \sin\theta \frac{(l + r\cos\theta)}{\sqrt{l^2 - r^2 \sin^2\theta}}$$

The above is identical with the formula for crankshaft torque.

Variation in Torque

The airplane engine of the internal combustion type receives its power in impulses. This tends to produce a variation in speed and since one of the engine requirements is practically

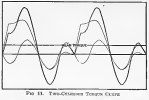


Fig 11. Two-Cylinder Torque Curve

a uniform speed, the variation must be minimized by storing the excess energy in a rotating member to provide for those periods when the energy is deficient. On some of the earlier airplane engines flywheels were employed, but this practice has long been discontinued since the propellers generally used have a moment of inertia sufficient to keep the speed variation within practical limits.

The greater the torque variation the greater must be the ability of the propeller to absorb the excess energy. An examination of the torque curves will clearly explain why so few engines having less than six cylinders are employed for the propulsion of aircraft. In the case of the rotary engine

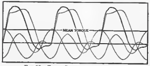


Fig 12. Three-Cylinder Torque Curve

the flywheel action of the propeller is supplemented by that of the mass of rotating cylinders.

The torque developed by one cylinder at any crank position can be computed by proper substitutions in the formula

$$T = F_r \sin\theta \frac{(l + r\cos\theta)}{\sqrt{l^2 - r^2 \sin^2\theta}}$$

when T = torque (lb. in.)
F = resultant force of gas pressure and inertia along cylinder axis
r = crank radius (in.)
l = length connecting rod (in.)
θ = crank angle (deg.)

The torque curve shown on Fig. 10 was plotted from values obtained in this manner and based on the performance of a well-known airplane engine running at its normal speed.

To obtain the resultant torque curve of an engine in which all the cylinders are functioning properly, it is only necessary to determine the algebraic sum of a series of curves (one for each cylinder of the engine) which have been plotted in relation to angular distances between corresponding points on their cycles. The resultant torque curves given on Figs. 11, 12, 13, 14, 15, and 16 were obtained in this manner for 2, 3,

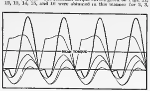


Fig 13. Four-Cylinder Torque Curve

4, 5, 6 and 7-cylinder engines, respectively, each in which the power impulses occur at even intervals.

In all other cases shorter methods were employed. For Vee type engines two single-cylinder torque curves were first combined at angles of 180 degrees plus that of the Vee so as to obtain the resultant torque of two cylinders operating

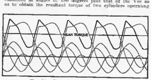


Fig 14 Five-Cylinder Torque Curve

about a single crank pin. Four of such curves, located at one-fourth of a cycle apart, were sufficient to determine the resultant torque curve for the eight-cylinder engines and six curves located one-sixth of a cycle apart, in the case of twelves. Three resultant torque curves of the three-cylinder

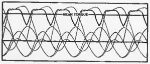


Fig. 15. Six-Cylinder Torque Curve

engine were combined to obtain resultant torque curves for the nine-cylinder, two five-cylinder curves were used for the ten, four four-cylinder curves for the sixteen and three six-cylinder curves for the eighteen.

The lower of the heavy horizontal lines is the line of zero torque. The value of any point on a curve above this line is positive and those which are on curves below are negative. In the latter case the torque is in the reverse direction and resists the power supplied to the driving member.

The heavy horizontal line designated Mean Torque is the average height of the resultant torque curve above the line of zero torque. This may be obtained either by measurement or mathematically if a sufficient number of values on the curves are used to avoid error. In a majority of cases and whenever possible it will be found that the quickest method is to compute the mean torque by the formula

$$T = \frac{\text{H. P.} \times 33{,}000}{2\,\pi N}$$

T = Torque (lb. ft.)
HP = Horsepower
N = Number of r.p.m.

Variation in torque is clearly illustrated by the waves made about the line of mean torque by the resultant curve. If the

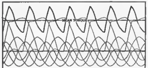


Fig. 16. Seven-Cylinder Torque Curve

speed actually varied in accordance with this curve we would without doubt have an intolerable condition. As previously explained, the excess energy is stored, so the actual variation in speed is due only to the amount of energy which the propeller is not capable of storing. Unless comparatively heavy and large diameter propellers are used with engines of few cylinders the greater torque variation may produce prohibitive variations in speed. This generally does not warrant any special attention on engines having six or more cylinders.

It is quite important, in correctly designing a crankshaft or

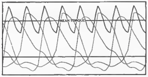


Fig. 17. Eight-Cylinder 90 Deg. Vee Torque Curve

any other member which transmits the power of the engine to the propeller, to know the magnitude of maximum instantaneous torque. Determining the same for each engine under consideration by computations and plotting of curves in the manner herein described, requires a considerable amount of time. It is a very simple matter to calculate the mean torque, therefore, if a ratio of maximum instantaneous to mean torque for a given number and arrangement of cylinders is known, the desired value, which is the product of the mean torque and this ratio, can be very easily obtained. The table below gives this ratio quite accurately for all the curves contained in this article. Any one ratio may vary slightly with different engines of a given type whose outputs are not identical, but as the values are approximately correct for the present-day type of airplane engine the use of this table is recommended for all practical computations.

Table of Torque Variation

Number or Arrangement of Cylinders.	*Ratio-Maximum Instantaneous Torque/Mean Torque.*
One-Cylinder	7.70
Two-Cylinder	6.20
Three-Cylinder	2.74
Four-Cylinder	2.94
Five-Cylinder	1.64
Six-Cylinder	1.17
Seven-Cylinder	1.45
Eight-Cylinder 90-deg. Vee	1.40
Eight-Cylinder 75-deg. Vee	1.42
Eight-Cylinder 60-deg. Vee	1.70
Eight-Cylinder 45-deg. Vee	2.14
Nine-Cylinder	1.22
Ten-Cylinder	1.12
Twelve-Cylinder 60-deg. Vee	1.13
Twelve-Cylinder 45-deg. Vee	1.25
Sixteen-Cylinder	1.06
Eighteen-Cylinder	1.05

An individual discussion for each torque curve is unnecessary. The reader will first note, upon examination of the above table, that the ratio and likewise the variation of torque

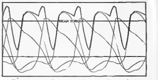


Fig. 18. Eight-Cylinder 75 Deg. Vee Torque Curve

is generally lowered by an increase in the number of cylinders. Due to the torque irregularity of one cylinder, there cannot be applied any fixed rule relative to the effects of additional cylinders. The table for example shows a slightly lower ratio for the three-cylinder engine than for the four. This is due to the fact that when three single-cylinder torque curves are

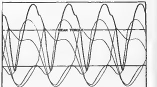


Fig. 19. Eight-Cylinder 60 Deg. Vee Torque Curve

combined 240 deg. apart it so happens that the larger values either do not coincide or are lowered by negative values on another curve. The six is also shown to be much lower than the seven-cylinder, hence there is reason to believe that three cylinders and multiples thereof produce good cylinder combinations from the torque variation standpoint even though the ratio as given for the twelve 60 deg. Vee type is not appreciably lower than that of the ten-cylinder.

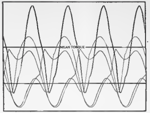


Fig. 20. Eight-Cylinder 45 Deg. Torque Curve

Attention is called to the increased ratio due to uneven fire impulses. This is best studied in the eight-cylinder Vee engine of which there are four examples. In the 90 deg. Vee eight, even firing takes place at intervals of 90 deg. of crank movement, while in the 75 deg. Vee the angular distances between impulses becomes 75 and 105 deg., in the 60 deg. Vee eight 60 and 120 deg., and in the 45 deg. eight 45 and 135 deg.

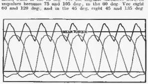


Fig. 21. Nine-Cylinder Torque Curve

respectively. The greater the deviation from even firing the larger becomes this ratio and likewise the torque variation. Since the same holds true in the one example of uneven firing given for the twelve we are inclined to believe that the least torque variation will always be identified with even distribution.

Our attention is next directed to the change of resultant torque curve characteristics as a result of uneven impulses of firing. Let it first be noted that the resultant torque curve of

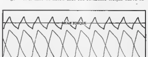


Fig. 22. Ten-Cylinder Torque Curve

all engines having even fire intervals appears, during one complete cycle, as many times as there are engine cylinders. At the slightest breaking up of even periods the peak of one curve is raised and on another it is lowered. The curve characteristics are consequently changed and we find only one half of the previous number of distinct repetitions of this curve.

The theory has been advanced that breaking up the firing order tends to lessen crankshaft torsional vibration. Obvi-

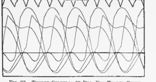


Fig. 23. Twelve-Cylinder 60 Deg. Vee Torque Curve

ously the number of highest curve peaks have been cut in half and can only synchronize with the natural period of the shaft half as many times, but the magnitude of maximum instantaneous torque is so increased that the author believes the stiffer crankshaft necessary to transmit this greater power will do more toward dampening torsional vibration than the reduction of high torque periods.

Nevertheless on account of the number of high torque periods per cycle the subject demands careful consideration. Even though the actual torque variation is diminished there is a possibility of serious difficulty due to the increased period

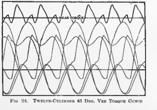


Fig. 24. Twelve-Cylinder 45 Deg. Vee Torque Curve

of synchronization produced by the greater number of cylinders together with the lesser degree of deflection allowable in a longer crankshaft which generally becomes necessary. In a well-balanced engine design, however, the increased strength necessary for transmitting the greater torque of more cylinders should automatically provide the required stiffness.

It is not out of place at this point to draw attention to the weight factor involved. We are all familiar with the engine weight as influenced by the various cylinder arrangements and that an increase in the number of cylinders seldom repre-

sents a weight increase in proportion to the addition of power. These conclusions are usually based on changes in the mass of metal which is so apparent. Let us consider this case on the basis of metal necessary for strength. In larger engines the increased length required for sufficient bearing areas hardly offsets the decreased weight per horsepower gained by the larger diameters of crankshaft journal necessary to transmit the greater torque because the strength increases as the cube of the diameter while the area increases only as the square.

The preceding discussion of torque reaction deals fundamentally with the reaction of one cylinder. Consider the same principle as applied to the reaction of the resultant torque developed by the engine as a whole. In this sense no regard is taken of cylinder location and the engine assembly is considered as being a perfectly rigid mass. The degree of variation which must be provided for at the engine supports is clearly illustrated by these diagrams. The designer should exercise great care in supplying the necessary rigidity to the engine supports and frame, otherwise vibration and longitudinal weaving will be set up as a result of these reactions.

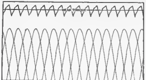


Fig. 25 Sixteen-Cylinder Torque Curve

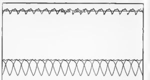


Fig. 26 Eighteen Cylinder Torque Curve

Suppose the above proportions are not altered; there are still sound reasons why the weight power ratio can be appreciably lowered in the engine having more cylinders. The crankshaft needs only to be strong enough to transmit the maximum instantaneous torque with a reasonable factor of safety; hence our comparisons should be based upon this value. This can best be illustrated by an example. If we wish to design an engine whose capacity is 50 per cent greater than a certain twelve of the 60 deg. Vee type we have the choice of two methods—increasing the cylinder capacity or increasing the number of cylinders. Unless there are very logical reasons for increasing the cylinder capacity we should naturally expect that building an eighteen-cylinder engine would be the best method, since the maximum torque to be transmitted in the former will be 113 per cent of the mean, while in the latter only 103 per cent.

Unless developments are forthcoming on larger cylinder capacities we will naturally look for the future engines of greater power output to have more cylinders. At the present time the limit appears to be the eighteen-cylinder engine which can develop possibly as high as 1000 hp.

The title of this article, Airplane Engine Vibration, may have appeared slightly misleading as the discussions have to a greater extent been comparisons of the various engine types as influenced by inertia balance and torque reaction with brief mention of torsional vibration. However, it was only intended to treat some of the principle sources of vibration in this manner. This places before us in a fairly complete form some comparative data which will assist us materially in our designs or in the selection of the same.

The difficulties of determining the degree of vibration as due to the various sources individually has already been pointed out. It will be observed that it has been necessary to use the resultant force of gas pressure and inertia in the development of the torque curves otherwise we would not have an exact measure of the torque effects. Since the vibrations due to the various sources appear collectively, our investigations insofar as the magnitude or detrimental effects are concerned, must end here.

Civil Aerial Transport in the United States

A Fleet of Curtiss Orioles Awaiting Reception Tests

Some Interesting German Airplanes

A very interesting set of photographs has just reached Aviation and Aeronautical Engineering from a foreign correspondent and is reproduced herewith to afford airplane designers an opportunity to study the most recent products of our late enemies.

Single Seater Pursuit Types

Fig. 1 shows the very latest type of single-seater fighter employed by the Germans just before the Armistice. This is a parasol type monoplane with no external wiring, and a very easily demountable strut arrangement at the center. The monoplane carries a very thick camber of the wing at the center. This machine was built by the Roland Aircraft Works and equipped with the new light German water-cooled six-cylinder vertical B. M. W. Bavaria engine, with overhead camshaft. The simplicity and cleanness of the design are noteworthy.

Fig. 2 shows as its pilot the late Baron von Richthofen in a modified form of the Roland "Whale" scout. It is interesting to note how careful the Germans are to fair the body into the wings, the skid into a lower fin. Evidently a rigid aileron control is in favor.

Apparently the question of fore-and-aft cross bracing in the center struts has been solved by building short veneer struts integral with the fuselage and supplying built-in moments in lieu of such wires.

Fig. 3 is another photograph of the same machine. Above the wing radiator a large expansion chamber is carried. The streamline of the veneer fuselage shows up very well. A vane anemometer is carried on the front outer strut. This type is termed Roland Doppeldecker D-III and was built by the Luft-Fahrzeug G. M. b. H. Abteilung Flugzeugbau.

The Roland Doppeldecker D-I (Fig. 4) is an earlier type from which the D-III was evolved. It is interesting to note that the Germans in this case discarded the fuselage built-up to the top wing, and gave the pilot vision below and above the wing. As in many other German machines a side glass panel is provided. A peculiar form of gun-mounting is seen here.

The same Luft-Fahrzeug Gesellschaft is responsible for a slight variation of the single seater Roland shown in Fig. 5. The most noteworthy feature here is the strip construction of the wood fuselage. Wing area below the fuselage has been saved by the lower, blade-like projection of the fuselage on the lower wing.

Apparently another single-seater of a curious type is shown in Figs. 6 and 7. This is a most peculiar aerodynamical conception, which has no doubt been adopted to combine the simplicity of a monoplane with perfect vision and fighting qualities. The flying wires are connected to the rear-strut of the peculiar three-strut chassis. The air intake is apparently very far forward on the under side of the fuselage. The propeller is so close to the engine proper that the radiator has to be cut

Fig. 1 (Top Left) Roland Parasol. Fig. 2 (Top Right) and Fig. 3 (Middle Left) Roland "Shark" Scout. Fig. 4 (Middle Right) Roland D-I. Fig. 5 (Bottom Left) Roland Scout. Fig. 6 (Bottom Right) and Fig. 7 (Centre). Sablatnig Monoplane

Fig. 8 (Top) Pfalz Pursuit Machine. Fig. 9 (Middle) Sablatnig Monoplane and Day and Night Patrol Biplanes. Fig 10 (Bottom) A E G Armored Ground Fighter

Fig 11 (Top) Zeppelin Two-Seater Fighter. Fig 12 (Left Upper Middle). Roland "Whale" C-II. Fig. 13 (Right Upper Middle) Roland C-VIII. Fig 14 (Left Lower Middle) Hannover CL-III Fig. 15 (Right Lower Middle) and Fig 10 (Bottom). Hannover CL-V

away in part in order to leave a good deal of the motor exposed. This design is the work of the Sablatnig Flugzeugbau of Berlin.

The Pfalz single-seater fighter illustrated in Fig. 8 is a peculiar design in which the removal of a couple of flying wires is more than balanced by the extra number of struts. An interesting type of radiator shutter is embodied on this machine.

Two-Seater Types

The A. E. G. two-seater of Fig. 10 offers few original features and can hardly be called an advance in design. The Zeppelin Works product of Fig. 11 is such a tractor, with all strut-end connections carefully hidden away and a single pair of outer struts, rendered possible by shortening the upper unsupported span by means of center section struts. The streamlining of the motor is interesting. Perhaps this is the best way to cover in a six-cylinder motor. In general considerable refinement is noticeable in the streamlining of this plane.

Of the various Roland two-seaters built by the Luft-Fahrzeug Gesellschaft, that of Fig 12, a C II equipped with a 160-hp Mercedes, presents the most interesting features, with an enormous outer I-strut and two side windows in the extremely deep "whale" body. In the very latest two-seater Roland the C-VIII, with 260 hp Mercedes (Fig 13), both the "whale" body and the I-strut have disappeared and a more conventional design is present.

The CL-III two-seater fighter of the Hanover Wagon factory (Fig 14), with its characteristic biplane tail, is already familiar to American readers. Its main interest lies in comparison with the later series CL V, two types of which are shown in Figs. 15 and 16. The engine is now entirely enclosed and the biplane tail is dispensed with in one example, though still present in another. The two outer interplane struts are definitely replaced by a single I-strut, and there is a single wire lift truss. The center section struts are also replaced by a single short strut, apparently built into the body. There is a rigid aileron control, with the lever at the center carefully sheltered by the wing. The most interesting point seems to be that the I-strut with single lift truss has been successfully employed.

Fundamentals of Rigid Airship Design*

By R. H. Upson
Aeronautical Engineer, Goodyear Tire & Rubber Co.

Rigid airships have made good. One may still criticize the rigid principle of design, but the double crossing of the Atlantic by the R-34 no one can deny. This unique system of construction developed by the energy and resources of a single man, was long ago taken up by a certain ambitious Government which early realized the importance of pushing the design to the limit, if at all. These airships have become indispensable in the operation of a large fleet, and in this respect the leadership in practical operation over sea has now passed to another country.

British design in general is based on information obtained about German Zeppelins, principally from those which have been brought down in England and France. The English designers admit very frankly they have been mainly copying German practice and that they are still behind what is probably the latest development in Germany. As one high officer expressed it, "We are so far behind them in airship construction as they are behind us in battleship construction." Nevertheless, the recent performance of the R-34 and other British airships show remarkable progress in every way. There is much of value to be taken from present British practice, which seems, at least, to have reached a point where the superiority of the German airships is largely a matter of refinement and development along fundamental lines that are now common to both countries. In addition, the British are also branching out into distinctly original lines of development.

Purpose and Advantages

Rigid airships are intended primarily for co-operation with the fleet over long distances and to a lesser extent for convoy work. Ordinary submarine patrol near the coasts is delegated by common consent to the non-rigid craft. The advantages of airships over large airplanes for co-operation with the fleet are so generally recognized that they need not be mentioned here. The advantages of the rigid over the non-rigid type for this purpose are quoted as follows from the statements of various authorities connected with rigid design and operation:

(1) Easier to control and maneuver than a non-rigid airship of equal size.

(2) No need to watch the pressure.

(3) No holding up of pressure at the high end when tilted.

(4) Sub-division into compartments makes for increased safety.

(5) Large proportion, over 50 per cent of the total in the latest ships, of useful lift.

(6) The rigid type offers convenient attachment for multiple power plants and propellers at such points as will distribute the load uniformly and prevent undue interference between various propellers.

(7) It eliminates a large amount of external cordage and fittings.

(8) Convenient access may be had during flight to any important part of the structure.

(9) Rigid construction offers great possibilities for sizes much larger than any now in use. [The R-34 is 2,000,000 cu. ft. and the latest Zeppelin is about 3,000,000 cu. ft. Already there are plans under way in England and Germany for ships up to 10,000,000 cu. ft. in volume. The largest American airship is 180,000 cu. ft.]

(10) For commercial use the rigid construction offers possibilities for passenger accommodation more substantial than in non-rigid types now in use.

In further comment on the above items, it must be said in all fairness that many of them are not inherent in the rigid principle of the design so much as in the way that particular ships happen to be built. For the ship to lift at all, there has to be a very light and fine construction throughout. This general type of construction is naturally extended to include the fins and cars where the weight is probably less than half and the resistance is also small for the size, compared with present types of non-rigid fins and cars. Likewise, to get a large useful lift there is a great refinement of construction in respect to the distribution of material. Thus, there are several different kinds of beams and columns built from various sections of which there are several different standards, and in the finished structure there is a very large variety with respect to the length, strength and distribution of the various elements. If one half as much pains were taken with the material in a non-rigid envelope, the gain in load-carrying efficiency would be considerable.

To prevent loss of gas and deterioration in quality which would otherwise result from the multiple-cell envelope, the interior balloons are made of goldbeater's skin spread on a 2-oz. cotton cloth which is very light but with a diffusion of only about 2 liters. This fabric is expensive and takes a long time to prepare, but with proper protection from the weather there is no fundamental reason why it should not be used with equal advantage in other types of ships.

Refinement is made in the power-plants and propellers to an extent unthought of in the non-rigid ships. Many other advantages often cited for rigid airships, such as range of action, carrying capacity and speed, may be more properly given as characteristics pertaining simply to large airships. Nevertheless, the rigid or Zeppelin construction is the only one which has to this date been used for sizes upward of 1,000,000 cu. ft. Hence, it is still the only generally recognized construction for large sizes, and as such must play a large part in the development of the immediate future.

* Courtesy of the Journal of Automotive Engineers.

General Principles of Framing

Every structural member subject to compression is built as far as possible so that it will be about at its critical point between secondary and primary failure. A column under such conditions has a certain proper length for each type of internal construction. If this construction is kept the same and the length increased, the failure on a compression test will be what is called primary, that is, the whole column will tend to bend and buckle. If tested shorter than this critical length, however, the column will fail internally. This same principle here described for the design of a main column would apply to the internal members composing that column. In an ideal column this would have the result of causing all internal members to fail by direct compression. All internal members are designed so that they have approximately equal strength under such conditions and give a uniform strength to the column as a whole, no matter what its length, providing this does not exceed the critical length. In the general system of design for any part, after ascertaining that the member in question is under or near its critical length, its ultimate strength is assumed to be that of the straight parallel members only without regard to the lattice or cross members. The main parallels of a beam or column are rolled to shape, the lattice members being stamped.

What is otherwise the ultimate strength of the material is usually reduced by 20 per cent to allow for the rivet holes, thus the duralumin now being used has an ultimate strength of 25 tons, but in practice only 20 tons is allowed. This is further subject, of course, to a factor of safety which in case of any definitely known worst conditions is two. This is in the case, for instance, where some accident happens such as would necessitate the deflation of one or two compartments. Under ordinary running conditions, it is aimed to have a factor of at least four throughout the structure.

The specific gravity of duralumin is about 3.0, which makes it equivalent in value to steel of 146,000-lb. strength. The weight of the lattice members and the rivets comprise about 40 per cent of the total weight of duralumin columns, such as are used for main longitudinal members. Wood instead of duralumin was used in the construction of two ships in England. This was found rather treacherous, as several parts were broken during flight under various conditions. When made of equal strength, the wood construction is slightly heavier than the duralumin and has the property of being much more flexible. During flight, the whole ship is said to bend quite perceptibly. This feature is not looked upon as desirable, although it is hard to say what disadvantage it can be in itself.

Commander Campbell, chief British designer, regards steel as unquestionably the material of the future for larger sizes. If they were going to build any more small airships of, say, 1,000,000-cu. ft. volume, he would be inclined to use wood, but for the larger sizes, 5,000,000 cu. ft. or more, he regards steel as the more efficient. High-grade steel is well known to be lighter for the same strength than anything else. The only reason it is not used for present sizes is because its high specific gravity makes it necessary to use such very thin sections.

Fabric

The internal balloons of the rigid ship are invariably made from goldbeater's skin and cloth in the following proportion:

Material.	Weight per Square Meter, g.
Cloth	65
Rubber	20
Cement	20
Goldbeater's Skin*	30
Varnish*	5
Total (Average)	140

The diffusion commonly runs as low as from 1 to 2 liters per sq. m., which is a very excellent result for the weight of fabric involved. The actual gas holding properties of the ships themselves are also extremely good. The disadvantage of the goldbeater's skin is that it takes such a huge number of animals to make a single balloon, and the skins have to be put through a rather complicated process of washing, scraping, drying, etc., to prevent decay. It is also said that this skin does not stand up very long under direct exposure to the weather. Attempts are being made in the laboratories to discover a substitute for goldbeater's skin which will have its good properties and yet be more satisfactory and dependable in other respects. An effective chemical substitute has not yet been produced, although encouraging results have been obtained with various glycerine and dope compounds.

The difficulty of supply will be somewhat modified by a recent discovery that there are other parts of the animal which may be made to serve the purpose practically as well as the true goldbeater's skin. The poor resistance to exposure is taken care of by the protective fabric covering over the outside of the hull as used on the typical rigid airship.

The outside covering is composed as follows:

Material.	Weight per Square Meter, g.
Varnish	10
Dope	25
Cloth	85
Total (Average)	120

The finish of the present covering is a kind of shiny green which is a rather good camouflage against the ground and also does not show very distinctly against the sky at night. It is reported unsatisfactory as regards durability and radiation properties, since it absorbs a considerable amount of heat and ultimately transmits this to the gas. It seems the latter fault could readily be counteracted by proper ventilation of the outside air space, but apparently there has been no special attempt made to do this. It is proposed to try an aluminum finish somewhat similar to the non-rigid envelopes next.

In general, the huge amount of fabric in one of these ships makes it of the utmost importance to save weight in every way possible. An avoidable increase of even a few grams per square meter is quite serious. The strength of fabric required cannot be well computed except from the results of experience. The internal gas bags must stand a maximum pressure at the top due to the head of gas plus about 10 mm., which is the usual opening pressure for the valves. It is not right to assume, however, that the fabric takes all of this pressure, as the gas bags are confined by other structural elements. Chafing on the gas files is minimized by putting this in the inside. The sharp corners of the framing and the wires are also well protected by suitable wrapping. The earlier ships also had a light netting to help hold the internal fabric in place, but this has recently been abandoned in favor of cords tied back and forth in the framing.

A General Comparison of Construction

The simplest comparison that can be made between a non-rigid and a rigid envelope is to imagine a beam which is required to stand a certain bending moment. The effect of the gas lift may then be evaded by considering the fabric beam merely inflated with air. Under such conditions, the following general propositions hold:

(1) The maximum moment which can be put on a properly designed fabric beam without tearing it is equal to one-half the moment required to buckle it.

(2) A rigid beam of similar size will carry twice the moment of a fabric beam of the same unit strength.

In practice, however, the second proposition is modified by the following factors:

(1) It is possible to obtain materials much stronger in tension than in compression. Drawn wire, for instance, may be had of a strength running from two to three times the best known compressive strength for the same weight.

(2) Any purely rigid structure is built up of internal members of which the compression members must be necessarily of a complex nature to avoid buckling. This necessitates a weight for the compression members nearly double what would otherwise be required to carry pure compression alone.

The net result of the theoretical basis above assumed would make a rigid beam somewhat heavier for the same strength than a flexible one. Another and still further factor, however, tends to reverse the result once more in its practical application. The two beams, as above assumed, are taken to be cylindrical in form and built of uniform material throughout. The latter would be necessary in the case of the fabric beam because the tension due to internal pressure is at all points the dominating one. In the case of the rigid beam, however, it is clear that proper refinement of design will permit cutting down the weight and strength of the structural elements toward the end of the beam where the bending moment is least. In other words, if a purely non-rigid beam, or balloon, is to resist certain maximum moments and forces of more or less local application, the whole beam must be subjected to the strain of an

* The weight is variable.

internal pressure which is determined by the conditions at these critical points. It might be suggested that by the use of internal compartments, a higher pressure could be carried in certain parts of the balloon than in others. This is a possibility, but involves so many undesirable features that it seems of doubtful practicability, at least for sizes now in use.

The only other solution to the general problem is the so-called semi-rigid construction, as exemplified by nearly all of the Italian balloons. This term "semi-rigid" has been loosely used at times to apply to any kind of compromise between a purely non-rigid and rigid construction. Here, however, I shall use the term to apply to a distinct type of construction, which is essentially different in principle from either the non-rigid or rigid. This does not, of course, prevent all these systems being used simultaneously in a single balloon, as, for instance, in the Forlanini type.

The purely semi-rigid construction may be defined as one which depends on internal pressure for nothing except to prevent the internal compression members from buckling. These members can then be made lighter, simpler and more compact than in the case of a purely rigid structure. In general the use of the semi-rigid construction so far as possible would seem to give most of the advantages of the pure rigid type without its principal disadvantage. There are many points, however, at which the semi-rigid construction is clearly not so effective as one of the others:

(1) The nose can be most effectively stiffened by a pure rigid construction.

(2) On small ships which can be made quite short, without having the diameter unduly large, the non-rigid construction in general is obviously most convenient.

(3) The larger a ship becomes, the longer it has to be made to keep down its weight. This necessitates progressively greater stiffness, which justifies the employment of increasingly more of the rigid elements.

(4) The power-plants on large, high-speed ships will need special attention as to bracing to distribute the thrust and torque properly.

(5) If a rigid structure is used for passenger accommodations, it may be placed so as to form a structural element in the ship as a whole.

It is doubtful, however, whether there is any practical size of dirigible which needs or should be made entirely rigid. The best design will always be that which combines proper proportions of all three principles to the best advantage for the particular size and requirements of the airship under consideration.

Conclusion

All things considered, the Zeppelin airship is admittedly the most advanced of any yet constructed. This is taking into account its size, detail features of design, and methods of handling. It is a product of over twenty years of work involving the active encouragement and financial support from the German Government and the best engineering talent in the country. The present Zeppelin is the same in fundamental construction but a truly immense improvement from a performance standpoint over the original creations of Count Zeppelin. The designers may have been handicapped by the necessity of adhering to this particular type of construction, but great gains were made possible by the way in which development was pushed, particularly in building much larger sizes than any one else had attempted. This not only gave to the "Super-Zeppelins" the huge aerodynamical advantages which accompany an increase in size, but it also permitted the utilization of those ultra refinements in construction which alone have made possible the splendid over-all efficiency of the present Zeppelins.

The broad lesson to be gained from British and German experience is obviously this: We should lose no time in starting development of the Zeppelin type ship, but we should also study other types of foreign ships and continue to work out our own systems of construction which promise so much for the future.

Pasadena Landing Field

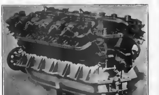
The city of Pasadena, Cal., has established a municipal landing field near the Altadena Country Club covering 80 acres, with all the equipment of a first-class landing field.

Navy Aviator Device

The Navy aviator device has been changed, according to a recent announcement of the Navy Department, reading as follows:

"The present gold pin with double wings based on the shield and anchor will be worn only on wash summer uniforms. The winter uniforms will carry a similar device of gold embroidery. Provision has been made in a new regulation which designates student naval aviators and flying mechanicians. The student wears a pin similar to that of the graduate aviator, with the exception that one wing is removed, leaving a device similar to that worn by observers abroad.

"Regular members of seaplane flight crews among enlisted men will wear a pin similar to that of the student aviator, except that it shall be of silver. This change is made



FIAT 700 HP. AIRPLANE ENGINE

in the belief that there should be a distinctive insignia for graduate and student naval aviators, and further that flying mechanicians should also be entitled to wear some mark of distinction."

The Air Service of the Army is considering the abolition of the half-wing now worn by its observers for the reason that it is deemed an anachronism, is illogical and open to criticism on the ground that it is scarcely dignified to an officer to mark him as belonging to a service in which he is not assigned to certain duty, in fact, is marked to indicate his restricted duty.

Suit Dismissed

Judge Augustus N. Hand of the United States District Court signed a final decree Aug. 20 dismissing the suit brought by the Curtiss Aeroplane and Motor Corp. against the United Aircraft Engineering Corp., of New York. Previous request for an injunction had been denied and the present decree terminates the suit and permits the United Aircraft Engineering Corp. to continue the sale of airplanes without interference.

Several months ago the United Aircraft Engineering Corp. purchased several hundred Canadian training planes and a large quantity of spare parts from the Imperial Munitions Board of Great Britain. The Curtiss Aeroplane and Motor Corp. claimed that these machines were infringements on various models made and sold by them and on which they claimed to hold patents, but evidence introduced in court disclosed the fact that the arrangements between the Canadian Aeroplanes, Ltd., of Canada, makers of the planes, and the Curtiss Aeroplane and Motor Corp., and the arrangements between the Imperial Munitions Board and United Aircraft Engineering Corporation were such that these machines may be sold in the United States without interference.

British Airplane and Seaplane Competition

The British Air Ministry has decided to institute an aircraft competition open to the British Empire with a view to obtaining "a real advance in the efficiency and design of airplanes and seaplanes and increasing the safety of air travel." The competition, which will be held commencing March 1, 1920, has been endowed with prizes aggregating £64,000. Machines and engines must have been designed and constructed within the British Empire, but this rule does not apply in the case of such secondary equipment as ignition and carburetion systems and instruments. This clause will be of decided interest to American manufacturers.

Airplane Competition

Two types of airplanes will be allowed to compete, namely, (a) a small type with a total carrying capacity of two persons including pilot, a minimum high speed of 100 m. p. h., a maximum low speed (flying level) of 40 m. p. h., both at ground level and with full load, and a climb of not less than 600 ft. the first minute starting from ground level; (b) a large type with seating accommodation for fifteen persons exclusive of crew, a minimum high speed of 90 m. p. h., a maximum low speed (flying level) of 45 m. p. h., both at ground level and with full load, and a climb of not less than 350 ft. in the first minute starting from the ground. The full load is to include in addition to the following instruments—revolution counter, aneroid, air speed indicator, turn indicator, compass, watch, oil pressure gage, air pressure indicator and radiator thermometer (the latter three where required)—for the small type—gasoline and oil sufficient to fly 450 miles at 3,000 ft. and a load of 440 lb. to include the weight of pilot and passenger, if carried, and parachutes; for the large type—gasoline and oil sufficient to fly 600 miles at 3,000 ft. and a load of 3,000 lb. to include weight of passengers, if carried, and respective parachutes, but not to include weight of crew. All machines must carry parachutes for all persons for whom accommodation is provided, including the crew.

The British government agree to buy the machine of each type winning the first prize, the designs to remain property of the manufacturers, at a maximum price of £4,000 for the small type and £10,000 for the large type. The following prizes are offered: Small type, first prize £10,000, second prize £4,000, third prize £2,000; large type, first prize £20,000, second prize £8,000, third prize £4,000.

Landing and Take-off Tests.—(a) A circle will be marked out on open ground to represent a field surrounded by obstacles. This circle will be of the following diameter:

Small machines	175 yd.
Large machines	275 yd.

The obstacles will be represented by a continuous string or tape with streamers attached, 50 ft. from the ground, of such a nature as to be easily broken by an airplane.

(b) The landing to be made in still air. Still air includes any wind not exceeding five miles per hour at ground level.

(c) During landing the machine is not to side-slip nor to turn, after reaching the obstacles, until it is on the ground. Once it has touched the ground the machine may turn in any direction.

(d) The machine to come to a standstill before reaching the marks representing the boundary of the field.

(e) After landing, the machine to get out of the same field over the 50 ft. obstacle in still air (as defined in sub-para. (b), no turn to be allowed until clear of the obstacle on the far side.

(f) No braking device operated by the engine may be used during landing.

(g) Any landing or taking off gear used must be integral with the machine.

(h) No landing apparatus may be used that in the opinion of the judges would be liable to cause undue damages to an aerodrome—*e. g.*, a claw attached to the machine as used on certain types of German machines would not be allowed, but the ordinary knife edge on a tail skid would be allowed.

(j) Both landing and taking-off to be with full load.

(k) Each machine will be allowed two trial attempts (which are definitely not to be counted as tests), and thereafter will be allowed four attempts, of which two must be successful.

Reliability Tests.—(a) In the case of the small type, each machine must carry out a series of two flights of 3½ hours at a speed, through the air, of not less than 80 m. p. h., starting with full load. Between flights machines will be left untouched, and under seal if necessary, a period of not more than 30 minutes being allowed before the second flight, for the purpose of filling up and normal examination.

No parts of the machine to be adjusted or changed without permission from the judges.

(b) In the case of the large type, each machine must carry out one flight of 7 hours' duration at a speed through the air of not less than 75 m. p. h., starting with full loads. Pilots may be changed during these flights.

Miscellaneous Provisions.—Machines must be capable of landing from a height of 500 ft., with their engines switched off or completely throttled down.

In a machine having two or more engines, the stoppage or retardation of any one engine must not prevent the machine from flying level nor cause it to get out of control.

Machines must be capable of being started from the cockpit or cabin without undue muscular exertion on the part of the pilot.

Machines to be capable of flying at cruising speed for 5 minutes without the use of any controls or stabilizing devices. Controls may be locked during this test.

Machines to be capable of standing unattended and not fastened down in a wind of 10 m. p. h., blowing in any direction with reference to the machine.

The design of the machines to be such that the risk of the machines turning over on a rough ground is reduced to a minimum.

Each machine to be provided with a complete outfit for pegging it out in the open. This outfit will not be carried as part of the load during tests.

Marks will be awarded for soundness and quality of construction, for general features and for exceeding the specified requirements, such as for exceeding maximum high speed, etc.

"Soundness and quality of construction" will include:—

(a) Fire protection, including use of self-sealing tanks, position of tanks (from the point of view of safety from fire in event of a crash), fire-fighting appliances and accessibility of same.

(b) Reliability of fuel, oil, and water systems and facilities for seeing if all tanks are full.

(c) Durability of machine including propeller (any advantages due to metal construction may be taken into account).

(d) Simplicity of design and accessibility of parts.

(e) Absence of vibration in the machine.

"General features" will include:—

(a) Efficiency and ease of control.

(b) Unrestricted field of view to the front for the pilot.

(c) Silence, as affecting occupants of the machine including crew.

(d) Comfort generally, including warmth.

(e) Self-starting devices.

(f) Method of wind screening adopted.

(g) Convenience for use of instruments.

(h) Freedom of entry and exit for occupants.

During or on completion of any flying test if it is necessary to effect any repairs to the machine after landing it will be considered to have failed in that particular test.

The rules applying to the seaplane competition instituted by the British Air Ministry, which will be held commencing at the same date as the airplane competition, that is, March 1, 1920, will be printed in the following issue of AVIATION AND AERONAUTICAL ENGINEERING.

Cross Continental Divide

The first planes to go over the Continental Divide were members of the Ellington Field Transcontinental Recruiting Squadron, pilots Lieut. E. W. Killgore, Lieut. C. V. Rugh, Lieut. E. H. Nelson, and passengers Sergt. A. M. Albert, Sergt. Y. Vierra, Sergt. G. W. Anderson, and Electrician J. J. Kelly. The party flew in four De Havilands from Glenwood Springs, Colo., to Denver, 130 miles, in 80 minutes. The highest altitude reached was 16,000 feet.


HISPANO-SUIZA
Aeronautical Engines
"The Motor that made the Spad possible"
EACH operation, however insignificant, is an important mile-stone in the fabrication of Hispano-Suiza Aeronautical Engines.
It follows then that correct engineering principle and design receive their greatest opportunity—exemplified innumerable times in this great motor's war-time performance.
Wright-Martin
Aircraft Corporation
New Brunswick, N. J.
Cylinder Drilling and Tapping

Doping Airplane Linen

By Geo. H. Hoff

The purpose of this investigation was to determine the effect of various coatings of cellulose acetate dope upon airplane linen.

Method—It was decided that the most natural way of determining the effect of dope on airplane linen would be to make up small planes similar to airplane wings and coat these in the same fashion.

Test pieces of linen were stretched across 15-in. squares, great care being taken to have the number of threads per inch in the warp direction the same on all test pieces, and the same number of threads per inch in the filler direction.

The cellulose acetate dope used was the same as that employed in the usual coating of airplanes and was considered very satisfactory. The test pieces were given one, two, three and four coats, each coat being permitted to dry at least 48 hr. All dope was applied under the proper conditions of temperature and humidity. Light and heavy coats were applied to see what differences resulted.

Tensile strength and stretch were observed under standard conditions. Temperature, 70 deg. Fahr. and 65 per cent humidity. Results are averages of 10 tests. The tests were made in laboratory of H. Behr & Co.

Results—The data below show the effects of light and heavy application of dope expressed in kilograms

Type	Warp or Lengthwise Direction		Filler or Cross Direction		Increase in Weight
	Kg	Per Cent Stretch	Kg	Per Cent Stretch	Oz. per yard
Linen	12 8	11 0	13 0	8 0	
1st coat	18 7	12 5	18 7	8 1	48
1st coat-b	18 2	12 1	21 0	8 2	92
2nd coat	16 8	12 8	19 1	8 8	64
2nd coat-b	17 2	12 3	21 8	7 4	97
3rd coat	16 9	14 2	20 8	7 0	92
3rd coat-b	18 4	16 7	21 1	8 3	1 66
4th coat	16 1	14 2	19 0	8 4	1 33
4th coat-b	19 8	16 8	25 0	8 8	3 01

Below are data showing increase in strength expressed as percentage

Type	Lengthwise Direction, Per Cent Increase	Cross Direction Per Cent Increase
1st coat	46	51
1st coat-b	42	61
2nd coat	31	46
2nd coat-b	34	67
3rd coat	32	60
3rd coat-b	44	88
4th coat	25	46
4th coat-b	55	92

Curves were also plotted showing the effect of the various coats on the stretch when tension is applied.

Discussion—In the test it was noted that the surface of the linen was cracked at about 9 per cent stretch where the strain amounted to about 12 kg. This effect occurred regardless of the number of coats. It is absolutely essential that in stretching airplane linen the material be so stretched that the threads in a given direction are absolutely parallel; otherwise, upon a slight application of pressure, very unequal strains result which produce cracking of the surface very quickly. From the accompanying curves it may be seen that very little variation in the stretch occurs between the various coats, what variation does appear is due to the original stretching of the linen upon the frame. The first coat is by far the most important, the remainder not causing any marked increase of strength. The fourth coat (b) shows an extremely high percentage increase in strength, but examination of a thread count showed 76 x 80 threads per in., as against a count of 72 x 76 in the remainder of test pieces.

The first coat must be a heavy coat, capable of easily penetrating the linen, as it is apparent that the remainder of coats are merely built upon it as a foundation. If the first coat is not firmly imbedded in the fabric, a slight strain will cause peeling or cracking to result. As the upper section of a coat dries first, its tendency is to curve outward and to shrink together. This is due to the unequal rates of drying between the

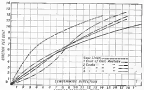


Fig. 1. Tensile Strength and Stretch in Lengthwise Direction

upper and lower sections of a coat, so that if the first coat is not firmly imbedded in the fabric, this curling in drying will cause the dope to practically peel off.

Conclusions—The first coat of airplane dope is by far the most important and practically produces the desired strength and tautness of the linen. Since the first coat is unquestionably the most important, great care should be taken to see that it has properly penetrated into the yarn between the interstices of the fibre and that it should have the proper viscosity and concentration.

The next coats can be considerably lighter in body as well as in concentration, and will produce the same effects as they do

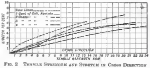


Fig. 2. Tensile Strength and Stretch in Cross Direction

under the present conditions; being lighter in body, they will enable the doper to apply them much more quickly and with less fatigue to himself, not to speak of the saving in cost of the cellulose acetate.

Since the first coat is the most important, the condition of the linen to which it is applied is of prime importance; if there is the slightest moisture in the linen it will prevent the proper penetration, it is quite obvious that airplane linen should be warmed to drive out the moisture, so that the dope can then easily penetrate without any danger of being precipitated by the moisture in the linen. Linked up with this is the condition of the humidity of the room in which the doping is done. This, of course, should be as nearly dry as possible.

Propeller and Fuselage Air Pressure Inter-Action

By D. L. Bacon

The experimental work forming a basis for this paper was performed (by permission of the United States Navy) on a fast seaplane designed and built by the Gallaudet Aircraft Corp. for bombing service (Fig. 1).

This machine has a nicely streamlined body, the uniformity of whose contour is broken only by two cockpit openings and the engine ventilation louvres. The radiators are mounted

Fig. 1. Dock Run, Liberty Wide Open, of Gallaudet D-4

in the upper wing, allowing an elliptical streamline nose; the motor is entirely enclosed, and the amount of piping exposed to the wind is reduced to a minimum.

The airplane is of the biplane pusher type, with the propeller swinging around the body at a distance from the nose equal to 55 per cent of the total body length. The tail is brought from a circular cross section at the propeller to a vertical chisel edge at the sternpost.

The present experimental work was undertaken as an attempt to analyze the resistant and propulsive characteristics incident to a combination of body and propeller. It is proposed, in view of the result obtained, to continue the investigations by comparative experiments, using other body contours and other propeller locations, including tractor types, or at

Fig. 2. Gallaudet D-4 Taxying Prior to Take-Off

least models in which the propeller is placed forward of the main wing section.

To determine the pressure distribution, a series of tubes were installed in the body, leading from a manometer board in the observer's cockpit to orifices at fifteen stations spaced along the horizontal meridian of the contour, as shown in Fig. 6. For test purposes the usual aluminum side sheet of the motor compartment was replaced by a temporary steel sheet without louvres, in order to eliminate possible discrepancies due to ventilation currents or eddies. Stations 12 to 15, inclusive, are adjacent to the stabilizer. In order to obtain an approximate mean reading, two orifices were used for each station, one above and one below the stabilizer plane. The lead to the manometer was taken from a Y connection equally distant from the two orifices. (See Fig. 3.)

A plate of .028 in. brass 1¼ in. square was drilled centrally to receive the end of a ⅛ in. O. D. brass tube, which was then soldered into it, after which the edges were chamfered and the surface smoothed. A hole was pierced through the fabric for the passage of the tube and the orifice fixed in place by riveting the plate to a small wooden block inside the contour, clamping the fabric between.

Preliminary experiments indicated that the thickness of the brass plate was not sufficient to cause any serious disturbance

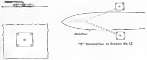


Fig. 3. Details of Air Pressure Leads

of the air flow. Air pressures were communicated to the measuring instrument through ⅛ in. brass tube.

The manometer board (Fig. 4) holds fifteen straight glass tubes connected from their upper ends to the corresponding stations along the body, and at their lower ends into a single horizontal header. The additional tubes X and Y, which also connect into the header, receive actual static air pressure from a specially constructed static orifice mounted on one of the struts (Fig. 5). Hence, a line drawn between the liquid levels in these two tubes (allowing for capillarity—Y is of large diameter to act as a reservoir for the alcoholic solution) may be used as a base from which all relative pressure readings are made. It is evident that the readings from this instrument are unaffected by changes of air pressure in the cockpit, as the system is air tight; or by the angle of the machine in flight, because the line of reference is automatically compensated.

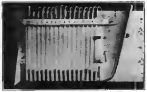


Fig. 4. Manometer Board

Photographic records were made of the complete manometric system during each run, the actual readings being measured later from scale prints.

On trying out the installation the pressure differences were found to be much greater than had been anticipated, the pressure at station 1 being so great, even at 60 knots, that it became necessary to disconnect that lead in order to avoid filling the system with air bubbles. In many cases the liquid

was found beyond the visible limits of the tubes, and finally the experiments were interrupted when, while gliding at a speed of over 100 knots, the entire mass of alcohol was sucked out through orifice 2.

The results obtained in flight are shown in Fig. 6 corrected and plotted from the photographic prints. All observed readings are indicated by small circles. Where these are lacking, the readings were off scale.

Curve I shows the pressure distribution while taxying on the water with the engine turning less than 1000 r.p.m. A slight depression is noticeable in front of the propeller, with an undulation toward the rear. Runs II, III and IV were all made at a speed of 60 knots, II being a climb (with 1520 r.p.m.), III horizontal flight (with 1120 r.p.m.), and IV

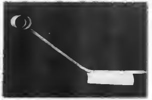


Fig. 5. Static Orifice for Mounting on Interplane Strut

a glide with engine throttled. The striking feature of these runs seems to be the proportionality of the depression forward of the propeller to its speed of rotation.

Curve IV resembles the characteristic curves for streamline spindles in free air, as obtained by Fuhrmann at the Gottingen Laboratories and by Eiffel at Auteuil. The contour of a solid of revolution equivalent to the fuselage used here shows considerable likeness to the model of the Clément-Bayard tested by Eiffel, and a corresponding similarity exists between its pressure curve and our Curve IV (Fig. 6). We, therefore, feel justified in assuming this curve to be the true characteristic of the body, and all others to be modifications due to propeller action. Curves V and VI show the distribution at horizontal speeds of 90 and 100 knots, respectively; the latter speed was attained with 1670 r.p.m.

In order to properly interpret these results, the area of the tail has been divided into zones corresponding to the various stations (see accompanying table). The projected areas of these zones upon a plane normal to the axis of the machine have been calculated and these areas multiplied by the pressures recorded for each zone. The summation of these figures, expressed in pounds, may be taken as a measure of the axial force due to air pressure. Between stations 9 and 3 the projected area of the zone is zero, the section being cylindrical, while for stations 1 and 2 the orifices are so far apart, while the changes of pressure and of contour are so sudden, that it was not thought practical to integrate the values obtained. Furthermore, the pressures and resistances at these points are affected comparatively little by the action of the propeller. The measurement of axial forces was, therefore, confined in all cases to that portion of the body aft of the propeller.

If the measurements obtained can be considered reliable, the results agree with the apparently paradoxical mathematical deduction published by Lanchester in 1908, "that it is theoretically possible that a vessel should be propelled for a less expenditure of power than that by which it can be towed."*

Machines of the type used in making the above tests have shown performance indicating an increase in effective propelling power above normal practice. The D-4, Liberty motored seaplane, used for these tests, with a flying weight of 4880 lb., made 124½ m.p.h. horizontal flight, and climbed 7700 ft. in 10 min. The D-2, twin Hall-Scott, single propeller seaplane, got off the water with one engine, carrying 39 lb. per hp., and flew with one engine carrying 43½ lb. per hp.

The most efficient combination of propeller and fuselage probably has not yet been reached, and in order to attain the best results more thorough research will be undertaken both in flight and in the laboratory. The general conclusion from these experiments emphasizes the value of considering the resistance of a fuselage as largely dependent upon the propeller and slip stream characteristics, rather than on simple coefficients obtained from wind tunnel tests of a model fuselage.

A Letter

Editor, Aviation and Aeronautical Engineering—We notice in the Editorial Notes of your issue of July 1, 1919, that in a description of the screw propeller theory you state that "Lanchester and Drzewiecki in 1909 first conceived a rational theory in which they assumed each blade element of the propeller as constituting an aerofoil."

We hold no brief for M. Drzewiecki, but we think it only fair to call your attention to the fact that M. Drzewiecki conceived this theory as early as 1892. In that year he presented to the French Académie des Sciences a paper entitled "Mémoire sur une méthode pour la détermination des éléments mécaniques hélicoïdaux," and on December 15 of the same year he presented a similar paper in the French Association Technique Maritime. These papers are to be found respectively in *Les Comptes Rendus de l'Académie des Sciences*, and *Le Bulletin de l'Association Technique Maritime*.

Mr. Lanchester conceived the same theory and published the same in his "Aerodynamics" in 1907. The date for the conception of the original blade element theory is so often misquoted that we welcome this opportunity of putting forward what we believe to be the correct date.

Henry C. Watts
London, England

*Completely described in N. A. C. A. report No. 14.

Pressure Distribution of D-4 Fuselage

Station No.	Projected Area of Zone Sq. ft.	Pressure in in. of water I	II	III	IV	V	VI	Thrust in lb. per Zone I	II	III	IV	V	VI
1	2.6	+0.1											
2	4.0	+0.1	.	−1.4	−1.8	−2.4							
3	0.0	+0.1		−0.4	−0.55								
4	0.0	+0.07	−0.73	−0.1	−0.45	−0.8	−0.2						
5	0.0	−0.04	−0.76	−0.18	−0.35	−0.4	+0.6						
6	0.0	−0.09	−1.35	−0.66	−0.6	−1.2	−0.6						
7	0.0	−0.07		−2.3	−1.16								
8	0.0	−0.15		−1.7	*	−2.1	+0.1						
9	0.4	+0.18	−0.4	−0.1	−0.09	−0.55	−0.2	−0.42	−0.09	+0.21	−1.35	−1.40	−0.41
10	0.9	−0.2	−0.38	+0.35	−0.28	−0.19	+0.6	−1.35	−1.87	+1.65	−1.14	+0.57	+3.48
11	0.7	−0.4	−0.6	+0.6	−0.2	+0.2	+1.0	−1.46	−2.17	+1.09	−0.73	+0.83	+3.54
12	1.1	+0.16	+0.2	+0.7	−0.2	+1.16	+0.85	+0.53	+1.14	+4.00	−1.71	+1.74	+4.84
13	1.2	−0.06	−0.76	0.0	−0.2	−0.06	+6.8	−0.62	−4.70	0.00	−1.24	−0.31	+4.08
14	1.3	+0.3	−0.48	−0.7	+0.5*	−0.6	+1.1	+2.02	−3.01	−4.05	+5.58	−2.35	+7.27
15	1.3	+0.38	+1.2	+1.2*	+1.2*	−2.5	+1.85	+2.20	+9.40	+9.40	+9.40	+10.50	+14.66
		Total on tail						+8.34	+2.04	+12.3	+6.66	+20.40	+38.40

Reading of scale.
* Readings indeterminable, values estimated.
All readings taken at an altitude of approximately 800 ft. temp. 32 deg. Fahr.

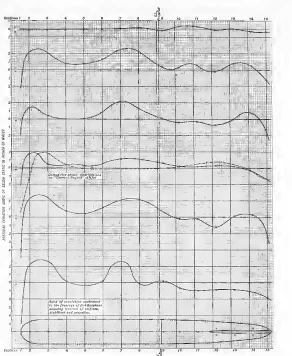


Fig. 6. Curves Showing Air Pressures at Different Stations on D-4 Fuselage

Civil Uses for Army Airships

The War Department authorizes the publication of the following from the Office of the Director of Air Service with regard to the relation of army airships to the civil departments and to commercial enterprises in time of peace.

The establishment of army airship bases throughout the United States and its colonial possessions will be a farsighted commercial policy and a great help to the civil departments in new enterprises. Airship sheds, gas plants, store houses and landing fields involve a large first cost and take a long time to procure or construct. Quite a large landing party is also required at each station.

An Army airship working, for instance, with the geological or forestry survey or the post office could be housed on an army reservation and be handled by a party of soldiers in its visits for fuel etc. it would cost much less to operate for the survey and would help keep the army airships employed in profitable work. Airship envelopes are perishable and it is expensive to replace a bag every two or three years and very unsatisfactory when it lies idle or is used merely to make practice runs. This same expenditure of time, gasoline, oil and repairs can serve a double purpose if the airship is used to help in transportation, surveys, bandit hunting or scientific researches.

That civil use most vital to the army is to assist the Department of the Interior in making the maps of the Geological Survey, which are the basis of the progressive military map. The Coast and Geodetic Survey can also use airships, especially over the vast coastal marshes where small details require larger expenditures on account of difficulties in transportation. The airship can transport survey parties with instruments and supplies to and from the tops of difficult mountains, to triangulation stations in wildernesses and to small islands that have poor landing facilities.

The airship will also be able to help the Mail service. In the great forests and mountains the airship is not handicapped in navigation, its compasses are steady and reliable. It can stand still over a neighborhood and by signals make its presence known to ground parties who can tow it in to a landing place, even in a thick fog. If the landing place is very small the airship can drop its guide rope and be pulled down among the hills and trees. There are many logging and mining camps that could get better mail service if there were airships available. The Yukon valley could have excellent mail service in summer if it had an airship line.

The airships will be useful to the Bureau of Mines because it can carry prospectors at low altitudes in their search for symptoms of minerals. It can fly close to the faces of great cliffs and along the steep slopes of the higher mountains. Over the deserts it will save great hardships. It can deposit prospectors with tools, instruments and supplies in neighborhoods needing close scouting and returning can take them out with their ore samples and data. If the period of search is long frequent visits with mail and supplies will be in order.

The Forestry service can use the airship to cruise timber areas, watch forests and visit areas under special investigation. It can supply lumber camps with light supplies and mail and bring passengers to and fro. With the airship it will be possible for scientists to closely watch the leafing, flowering and shedding periods of large areas. The tree life on difficult mountains can be more closely studied. Seeds may be spread over new areas. The action of fires can be closely watched and fire fighters can be let down where needed. In tropical forests trees of great value can be hunted for by their flowers, leaves or other symptoms seen from above without sending white men into insect ridden jungles.

In the river and harbor work the airship can study the snow areas, the flow of tributaries and even stay out for days while engineers in charge can study the progress of floods. With this better knowledge the probable extent of floods can be predicted with great accuracy and more intelligent means taken to control the rivers. The tide rifts can be studied from great altitudes and harbor improvement work will be benefited. Reefs can be detected on clear days and charted.

In studies of animal and insect life the zoologist and entomologist can have the same facilities as the geologist. Transplanted animals can be more closely watched, the great deer herds of Alaska can better be protected and illegal drives can be stopped. In countries where migratory insects, like locusts, need surveillance, scientific measure can be taken to find their breeding places and sterilize the egg laden areas. An airship can follow a locust cloud and by the use of gases and explosives disperse it or drive it away from valuable crops.

The fisheries can use the airship to detect schools of fish. These look like clouds on the water and from high places can be pointed out to fishing fleets the same as the Philippines use the hills near Manila Bay.

The Revenue Guards and the Department of Justice can use the airship to detect smugglers and to pursue large bands of outlaws, especially if they are mounted or have stolen livestock or property in vehicles. The military and civil patrol of the Mexican border will be able to cooperate in suppressing international lawlessness.

Stern of the British Airship R-33, with Lookout Post
Central News Photo Service

The Department of State will find the airship especially valuable in carrying out diplomatic missions in time of war or peace because of the secrecy and economy of time afforded. For instance missions to landlocked countries can be managed even though enveloping territories object, since the route cannot easily be closed or even proven.

The consular service will be able to visit remote regions in search of commercial data. It will often be possible to warn our nationals of impending famines or eras of plenty. Samples of new or improved products or remote places can be obtained even though there are no good land or water routes.

The Department of Agriculture can use the airship to analyze crop conditions. A good judge of crop conditions could thus survey in person an entire state like Ohio in very few days. It is in the great plains of the northwest that such use is most valuable.

N. A. C. to Erect Laboratory

At a meeting of the National Advisory Committee for Aeronautics, recently, the construction of an engine dynamometer laboratory was authorized. The laboratory will be erected on the Committee's plot at Langley Field and will cost approximately $15,000.

The purpose of the laboratory is to test internal combustion engines, conduct researches and advance the development in aircraft engines. The study of related problems, including the co-relation of engine performance in free flight with the results obtained on the test stand, will also be made.

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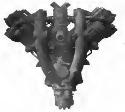

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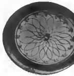

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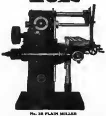

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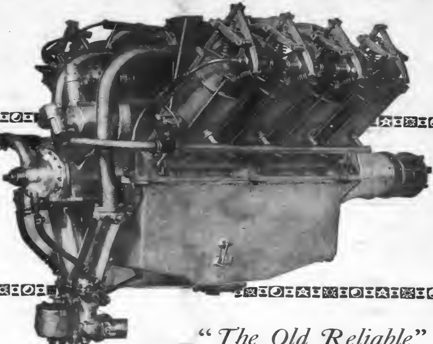

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